LEVEL II

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TECHNICAL REPORT PTR-1060-77-11

WHAT MAKES A GOOD EXPLANATION?

DECISION RESEARCH • A BRANCH OF PERCEPTRONICS

Baruch Fischhoff
Solomon Fulero

12

November 1977

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Sponsored by

Defense Advanced Research Projects Agency
ARPA Order No. 3469

Under Subcontract from

Decisions and Designs, Incorporated

15 N00014-78-C-0100, ARPA Order-3469

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11 November 1977

12 45 p.

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SUMMARY

Overview

A series of experiments examined the subjective criteria which people use when evaluating alternative explanations for everyday events. It was found that they typically rely on a strategy which is inappropriate according to most theories of how one should explain events. The implications of these results for the effective interpretation of events are discussed.

Background

A key element in command and control tasks is evaluating alternative explanations of observed events. For example, "Is his performance so lackluster due to lack of ability or lack of motivation?" "Is the brusqueness of his response due to rudeness or anxiety?" So many such decisions must be made in a working day that it is often impossible to do the sort of detailed data collection and analysis needed to produce the best possible information.

Approach

The present studies ask "What subjective criterion do people use when forced to make quick evaluations of alternative explanations?" and subsequently, "How appropriate is that criterion?" First, a set of possible criteria was identified. Second, a set of explanation situations was developed which discriminated between those criteria. Third, it was determined which of these criteria best predicted judgments of "better explanation."

Findings and Implications

The subjective judgment which best predicts which of two possible causes is judged to be a better explanation of a given event is: "Which of these two causes is more likely to have been present given that the event occurred?" This judgment measures the necessity of the causes given the event. According to most (if not all) philosophies of science, one should, however, be asking about the sufficiency of the cause to produce the event, i.e., "How likely is the event given the cause?" Use of the necessity criterion can severely restrict the extent to which the explanation of past events improves our ability to predict future events. Possible reasons for this bias and ways to ameliorate it are discussed.

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We would like to thank Barbara Combs and Gerry Hanson for conducting the experiments, Nancy Collins and Peggy Roecker for typing, Bernard Corrigan and Mark Layman for computing, and Sarah Lichtenstein, Harriet Shaklee and Paul Slovic for discussing various aspects of this project.

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by Office of Naval Research under Contract N00014-78-C-0100 (ARPA Order No. 3469) under Subcontract from Decisions and Designs, Inc., to Oregon Research Institute and Subcontract 78-072-0722 to Perceptronics, Inc.

1. WHAT MAKES A GOOD EXPLANATION?

Event E occurs and two possible causes, C_1 and C_2, are offered. How does one decide which provides the better explanation?

The most widely accepted proposal for how one should make such judgments is offered by the hypothetico-deductive or covering-law model of explanation (e.g., Hempel, 1965). According to that model, an event has been explained when one has identified a set of initial conditions, C_i, and general laws of behavior, L_j, such that $P(E|C_1, \ldots, C_i, \ldots, C_n; L_1, \ldots, L_j, \ldots, L_k) = 1$. That is, an event is explained when one has shown it to have been inevitable. Thus, explanation is a form of after-the-fact prediction (or postdiction). Of two sets of initial conditions, the better explanation is provided by the one which makes E more likely. Assuming that the set of laws, L_j, are the same when considering C_1 and C_2, the better explanation is provided by the cause for which $P(E|C_i)$ is greater.

Among philosophies of science, the leading competitor to the covering-law model is the coherence or colligation criterion (e.g., Gallie, 1964), according to which the best explanation is provided by the cause whose conjunction with the event produces the best story. Thus, the coherence criterion invokes a qualitative, quasi-aesthetic judgment. It is advanced most frequently by historians who contend that the covering-law model is appropriate to physics, but not to a profession dealing with unique (i.e., behavioral) events. In Walsh's words (1967),

> ...the historian's aim is to make a coherent whole out of the events he studies. His way of doing that, I suggest, is to look for certain dominant concepts or leading ideas by which to illuminate his facts to trace the corrections between those ideas themselves and then to show how the detailed facts became intelligible in the light of them by constructing a 'significant' narrative of the events of the period in question. In this respect the ideal of the historian is in principle identical with that of the novelist or dramatist (p. 61).

Belief in the prescriptive validity of these criteria need not entail belief in their descriptive validity.[1] The present study examines the criteria which people invoke when asked: Is C_1 or C_2 a better explanation of Event E? Some subjects were asked to choose one of two causes as the better of two explanations for each of a large set of events. Other groups judged the relationship between the same causes and events by various criteria which have been advanced as constituting the equivalent of "being a good explanation," among them the hypothetico-deductive and coherence criteria. Our goal was to discover which of these alternative criteria produces responses most similar to those elicited by the question, "which provides a better explanation?"

A similar approach was adopted by Bear (1974) to validate his contention that one particular subjective criterion, $P(E|C_i)$ is equivalent to the "good explanation" judgment. For five items, he found that if C_1 was chosen as a better explanation than C_2, then $P(E|C_1)$ was judged to be greater than $P(E|C_2)$.

Unfortunately, in each of his examples, one of the two possible causes had nothing at all to do with the event. Therefore, almost any reasonable judgment [not just $P(E|C_i)$] would associate the relevant cause with the event in his examples.

2. EXPERIMENT 1

2.1 Method

Every task involved an event, E, and two possible causes, C_1 and C_2. Each task required subjects to make one of eight judgments, each resulting in the choice of either C_1 or C_2. Three of these judgments were variants on the question, "which is a better explanation for E, C_1 or C_2?" The remaining five were other judgments which might be the subjective equivalent of "better explanation."

2.1.1 Explanation Tasks

Explanation 1 (both true). Before deciding which cause makes a better explanation, one might want to know whether both or only one of the causes is true. One group of subjects was asked to assume that both facts were true and to choose that which provided a better explanation. An example of their task read:

> A person stole office supplies from his place of work. Both of the statements below describe that person. Which of the two would be a more adequate explanation of this action or event?
>
> A. The person was poor.
> B. The person was unreliable.
> C. No difference (A and B are equally good explanations).

Explanation 2 (only one is true; ignore likelihood of causes). If one is told that only one of the facts reported in

the two cause statements is true, should one consider the likelihood of each statement being true when determining which makes a better explanation? For example, one might encounter a situation where, if true, C_1 would make a much better explanation than C_2 (if true); however, C_1 is unlikely to be true. To clarify this aspect of the explanation task, two separate "only one is true" conditions were created. Explanation 2 completely ignored the likelihood of the causes:

> A person stole office supplies from his place of work. Only one of the following statements is true about this person. Which of the two, if true, would be a more adequate explanation of this action or event?
>
> A. The person was poor.
> B. The person was unreliable.
> C. No difference (A and B would be equally adequate explanations).

Explanation 3 (only one is true; consider likelihood of causes). This condition made explicit reference to the relative likelihood of the causes:

> A person stole office supplies from his place of work. Only one of the following statements applies to this person. Which of the two is more likely to be an adequate explanation of this action or event?
>
> A. The person was poor.
> B. The person was unreliable.
> C. No difference (A or B is equally likely to be an adequate explanation).

2.1.2 Alternative Criteria

Prospective probabilities $P(E|C_i)$. Five alternative criteria were used. The first, called prospective probabilities, operationalizes the hypothetico-deductive criterion:

> Assume that two people have been described to you.
> Person A: Was poor
> Person B: Was unreliable
> Knowing what you know about people, which of these two is more likely to steal office supplies from his/her place of work?
>
> ______ Person A
>
> ______ Person B
>
> ______ No difference (equally likely).

Retrospective probabilities $P(C_i|E)$. The second criterion, retrospective probabilities, has not been proposed as a prescriptively valid rule. We include it as the result of speculating that people may ask "Which cause is more likely given the event?" rather than "Which cause makes the event more likely?" That is, perhaps people look at $P(C_i|E)$ rather than $P(E|C_i)$. $P(E|C_i$, or prospective probabilities, captures the sufficiency of the cause for the event. $P(C_i|E)$, or retrospective probabilities, captures the necessity of the cause given the event. Although use of such a criterion would violate the "rational" covering-law model, it might still be an accurate description of what people do. It suggests, for example, a detective trying to work backward from events to causes.

A person steals office supplies from his place of work.
Is this person more likely to

A. Have been poor.

B. Have been unreliable.

C. No difference (A and B are equally likely).

Coherence. The third criterion was an operationalization of coherence. One reason for considering coherence as the criterion for explanatory adequacy, other than some historians' insistence that it should be, is the great difficulty that people have with probabilistic inference tasks (Tversky and Kahneman, 1974). A non-probabilistic criterion asking for a quasi-aesthetic judgment might thus be very attractive to such individuals:

Which of the following makes for a more coherent short narrative (i.e., which is more thematically unified, which sticks together better)?

A. A person who was poor stole office supplies from his place of work.

B. A person who was unreliable stole office supplies from his place of work.

C. No difference (both narratives are equally coherent).

Representativeness. Another deterministic criterion suggested by the literature on probabilistic inference is judgment by representativeness. Kahneman and Tversky (1973) have shown that "intuitive predictions follow a judgmental heuristic -- representativeness. By this heuristic, people

predict the outcome that appears most representative of the evidence" (p. 237). Representativeness is thus a judgment of "fit" or similarity between the outcome predicted and the situation out of which it arises. In predictive tasks, judgment by representativeness has been shown to produce some important judgmental biases. As a criterion for explanation, it might suggest that judgments such as "that's just like him" constitute adequate explanations. One such example might be Lerner's (1970) "just world" theory, according to which people attribute bad outcomes to the badness of the people to whom they happen. An example of this task is:

> A person stole office supplies from his place of work. Is this action or event more fitting and appropriate for:
>
> A. Someone who was poor.
> B. Someone who was unreliable.
> C. No difference.

Availability. The final nonprobabilistic criterion is also suggested by a Tversky and Kahneman (1973) heuristic, "availability," according to which an event seems likely to the extent that it is easy to imagine how it could happen. Perhaps a cause explains an event according to the ease which which the gap between C_i and E is filled, that is, according to how well the cause enables the explainer to see how the event happened:

A person stole office supplies from his place of work. Can you more readily see how

A. Someone who was poor

B. Someone who was unreliable

would come to take this action or have this happen to him or is there

C. No difference.

No claim is made that these five alternative criteria are distinct. Indeed, it will shortly be seen that they often coincide: causes that combine with events to make coherent narratives often make the event seem likely and seem likely given the event. We know, however, too little about the relationships between these five criteria to be able to specify in advance just how they will differ. For example, Tversky and Kahneman do not specify whether representativeness or availability will be invoked in situations where both heuristics are applicable. The first step in this investigation was to discover situations in which these criteria produce differing judgments. We could then ask, to the extent that they do differ, which alternative is the best predictor of judgments of explanatory adequacy?

2.1.3 Item Development. Contrasting these eight judgmental tasks requires a set of items which discriminates between them. Items were written which seemed to us to discriminate between one or more pairs

of judgments. If, after being presented to subjects, an item did discriminate between tasks, it was kept; if not, it was dropped.

Items were presented to two waves of subjects. The first wave consisted of 8 groups (one per criterion), each of which judged the same 39 items. Of these items, 19 were eliminated[2] because: (a) a majority of all subjects chose the same alternative (A or B) in each of the 8 conditions, and (b) the proportion of subjects selecting A was not significantly different in any two conditions, as determined by a multiple range test (alpha = .20). The remaining 20 items were combined with an additional 20 items and presented to a second wave of 8 groups. Three of the old items and 7 of the 20 new items were eliminated from wave 2 because of universal agreement (as defined by [a] and [b] above). The remaining 30 items were used to determine the degree of agreement between the different judgments.

Explanation 1 (both causes true) is not applicable to items for which the two possible causes are contradictory. Such items are usable on the other conditions and some were included. Fifteen items in the original set for wave 1 and seven items in the set remaining after wave 2 were of this type. Analyses referring to Explanation 1 involve only the items with non-contradictory causes.

2.1.4 Subjects. A total of 282 paid subjects participated in the two waves of the experiment. They were recruited by advertisements

in the University of Oregon student paper. Approximately 15 subjects were in each of the eight conditions in wave 1 (range: 14-17); approximately 10 saw each type of questionnaire in wave 2 (range: 18-21).

2.1.5 Procedure. Questionnaires were completed in self-paced groups of 30 to 40 subjects, with the 8 forms being distributed unsystematically among the subjects in each group. After judging the 39 items, wave 1 subjects evaluated their task on 7-point rating scales for interest, familiarity, ambiguity and degree of challenge.

2.2 Results

2.2.1 Measures. Items were assigned two scores: A/All = the number of subjects selecting alternative A divided by the total number of subjects in a group; and A/AB = the number of subjects selecting alternative A divided by the number of subjects selecting A or B (and not C). A/All gives the overall popularity of alternative A; A/AB gives its popularity among subjects who could decide between A and B. If analyses based on both of these scores are not reported, it can be assumed that the same conclusions were reached for the unreported score.

There were substantial differences between subjects in ability (or willingness) to choose between A and B. For each of the 8 tasks there was a bimodal distribution for the number of C (no difference) responses per subject, with most subjects

giving C for 10-20% of the items and a minority giving C for about half. There were also substantial differences in the proportion of C responses per item. In wave 1 that proportion ranged from .12 to .54. However, the proportion of C responses did not differ greatly across the eight tasks (range: .19 to .26).

The seven-point interest scales administered at the end of wave 1 showed few large differences among the eight tasks. However, prospective probabilities were clearly viewed most favorably, with the highest mean rating on "interesting," "not ambiguous" and "familiar," and the second highest rating on "challenging." Availability received the worst rating on "interesting," "challenging" and "not ambiguous," although it was slightly above average on "familiar."

2.2.2 Overlap. Even though the items were designed to discriminate between the conditions, there was still great similarity in responses across the various conditions. The fact that only 30 to 59 items remained after wave 2 is one indication of this overlap. The correlations among the proportions of A responses for the different tasks, across all items used in wave 1, including those eventually deleted, were very high. They ranged from .52 to .93 with medians of .83 for A/All and .80 for A/AB. Principal components factor analyses revealed that about 80% of the variance in these scores could be accounted for by one factor. Although all variables loaded highly on this one factor, prospective probabilities had the lowest loading for both A/All and A/AB.

Table 2-1 shows the intercorrelations among the tasks for the 30 discriminating items remaining after wave 2. These correlations were based on A/AB. Results based on A/All, which correlated .93 with A/AB, were essentially the same.

Although the intercorrelations were high, they were not as high as the correlations based on all items used in wave 1; the median correlation in Table 2-1 is .58. In addition, several clear patterns emerge. The three explanation judgments were highly similar to one another. Multiple-range tests (using alpha = .20 as a cutoff) revealed only two cases among the 30 items for which any of the explanation tasks differed from one another. Either subjects do not distinguish between these tasks or our items and procedure failed to elicit whatever distinctions they can make. Whatever the case, in the present data these three conditions are best treated as one.

Among the five alternative criteria, two clusters emerged. One involved prospective probabilities and coherence, and the second involved retrospective probabilities, representativeness and availability. The mean correlation (using Fisher's Z) between variables within the same cluster was .66. The mean correlation between variables in different clusters was .50. This clustering was supported by the multiple-range test analyses. Of 29 disagreements (alpha = .20) between pairs of five alternative criteria, 26 involved criteria belonging to different clusters. Apparently, the coherence judgment evokes a forward-looking perspective like that of prospective probabilities, whereas representativeness and availability induce people to look backward from events to antecedents in the manner of retrospective probabilities.

TABLE 2-1

CORRELATIONS BETWEEN JUDGMENT TASKS FOR PROPENSITY TO CHOOSE A ON 30 DISCRIMINATING ITEMS

(Score: A/AB)

Task	Expl. 1	Expl. 2	Expl 3.	Pros. Prob.	Retro. Prob.	Coher.	Rep.	Avail.
Explanation 1[a]		.77	.62	.30	.53	.56	.73	.63
Explanation 2			.65	.35	.58	.40	.73	.71
Explanation 3				.25	.73	.36	.63	.71
Prospective Probabilities					.35	.59	.55	.44
Retrospective Probabilities						.42	.58	.69
Coherence							.70	.48
Representativeness								.75
Availability								

[a]Correlations with Explanation 1 involve the 23 items with non-contradictory causes (for which that condition existed).

Of these two clusters, the one involving retrospective probabilities was more highly related to the explanation judgments. The mean correlation between members of this cluster and the three explanation judgments was .77, while the mean correlation between explanation and the members of the prospective probabilities cluster was .37. The difference between the two sets of correlations was highly significant ($z = 3.18$, Mann-Whitney U test). Looking at the multiple-range test, of 30 instances in which judgments in an explanation task differed significantly from those in an alternative criterion, 15 involved the remaining three criteria (4 with retrospective probabilities and 2 with availability). Thus, 80% of the disagreements were with the prospective probability cluster. Principal components factor analyses performed on the matrices in Table 2-2 showed two factors accounting for about 80% of the variance. One factor had large loadings for prospective probabilities and coherence; the other factor showed large loadings for the remaining 6 variables.

2.2.3 Individual Events. To help clarify the nature of the difference between these clusters, Table 2-3 presents the 4 items which produce the greatest overall multiple-range test effect. Responses are pooled across the tasks in each cluster. For example, 22 Explanation 1 subjects, 21 Explanation 2 subjects, and 22 Explanation 3 subjects picked being unmarried as the best explanation for Event 1, producing the 65 in the upper left hand corner. For all the examples shown in Table 2-3, the cause labeled A is the cause most often chosen as the best explanation and most often chosen by the subjects in the retrospective

TABLE 2-2

STIMULI USED IN EXPERIMENT 2

Cause	Event		
Item 1			
	Live alone	Do not live alone	Phi
Is unmarried	30	30	.25
Is married	10	30	
Is a shy, easily embarrassed recluse	9	1	.34
Is not a shy, easily embarrassed recluse	31	59	
Item 2			
	Is a heavy smoker	Is not a heavy smoker	Phi
Has friends who smoke	18	72	.00
Has no friends who smoke	2	8	
Has a deep-seated inferiority complex	10	10	.38
Does not have a deep-seated inferiority complex	10	70	
Item 3			
	Signed a "Jail Nixon" petition	Did not sign a "Jail Nixon" petition	Phi
Is a Republican upset with Watergate	3	27	.00
Isn't a Republican upset with Watergate	7	63	
FBI agent looking into subversive activities	1	0	.32
Not an FBI agent looking in subversive activities	9	90	
Item 4			
	Works as a computer programmer	Does not work as a computer programmer	Phi
Is orderly	3	22	.30
Is not orderly	0	74	
Is an avid "Star Trek" fan	2	8	.33
Is not an avid "Star Trek" fan	1	89	

NOTE: In each pair, first cause is more necessary, second cause is more sufficient.

TABLE 2-3

NUMBER OF PERSONS SELECTING EACH ALTERNATIVE
FOR FOUR SELECTED EXAMPLES

Event and Alternatives	Explanation Cluster		
	Expl.[a]	Retro.[b]	Prosp. Cluster[b]
Event 1. Lives along			
A. A person who is unmarried	65	57	6
B. A person who is a shy, easily embarrassed recluse	23	29	58
C. No difference	18	17	9
Event 2. Is a heavy smoker			
A. A person who has friends who smoke	74	74	25
B. A person who has a deep-seated inferiority complex	20	10	33
C. No difference	12	17	15
Event 3. Signs of "jail Nixon" petition			
A. A person who is a Republican upset with Watergate	66	55	24
B. A person who is an undercover agent for the FBI looking into subversive activities and eager to appear opposed to the establishment	21	21	42
C. No difference	19	27	7
Event 4. Works as a computer programmer			
A. A person who is orderly	72	64	27
B. A person who is an avid "Star Trek" fan	14	13	23
C. No difference	20	26	19

a Pooled across the three explanation tasks.
b Pooled across the retrospective probability, representativeness and availability tasks.
c Pooled across the prospective probability and coherence tasks.

cluster of tasks. In our judgment, this cause, A, also has the highest base rate; that is, there are more unmarried people in the general population than shy, easily embarrassed recluses, and there are more upset Republicans than undercover FBI agents, etc.

2.4 Discussion

To the extent that the five alternative criteria produce differing judgments, they fall into two clusters, one involving prospective probabilities and one involving retrospective probabilities. Judgments of explanatory adequacy are considerably closer to judgments of retrospective probability than to prospective probability. Another way of viewing this result is as follows: When $P(A/E) > P(B/E)$, A constitutes a more necessary antecedent of E. When $P(E/A > P(E/B)$, A constitutes a more sufficient antecedent of E. The retrospective probability condition elicits a judgment of relative necessity, while the prospective probability condition elicits a judgment of relative sufficiency. To the extent that judgments of necessity and sufficiency diverge, our subjects allowed necessity to guide their judgments of explanatory adequacy.

Of course, given the high intercorrelations within the clusters, it would be just as true to say that when judgments of coherence (a member of the prospective probability cluster) and availability (a member of the retrospective probability cluster) diverge, the latter provides a better predictor of explanatory adequacy. At the moment, we cannot tell whether judgments of retrospective probability, representativeness and availability can ever be reliably distinguished or which is the "real" surrogate of "better explanation." We will, however,

use the terms "necessity" and "sufficiency" to identify the prospective probability and retrospective probability clusters.

Why, when forced to choose, do people prefer the more necessary to the more sufficient explanation?

In the discussion of Table 2-3, we noted that in each of the four examples, the more necessary cause appeared to us to be more likely. Indeed, it can be shown that when $P(C_1|E) > P(C_2|E)$ $P(E|C_1) < P(E|C_2)$ then $P(C_1) > P(C_2)$. That is, if one of two causes is more necessary and one is more sufficient, then the more necessary cause must be more likely. Perhaps people prefer not to invoke unlikely causes as explanations. A normative justification for this policy would be that people are interested in the overall (bidirectional) "correlation" between causes and events, perhaps in keeping with Kelley's (1973) covariation principle. The prospective probability and retrospective probability criteria provide unidirectional measures of association, expressing the predictability of events from cases and causes from events, respectively. A bidirectional measure of association, say ϕ or λ, would reflect both of these aspects. Consider such a correlation coefficient applied to 2 x 2 contingency tables whose rows are labeled "cause i present" and "cause i absent" and whose columns are labeled "event occurs" and "event does not occur." When such tables are constructed for each of the two causes proposed for a given event (as shown in Table 2-2), both tables have the same column marginals. However, row marginals differ, reflecting the base rates of the various causes. In general, the more extreme the row marginals. the smaller the bidirectional correlation between cause and event will be. To recapitulate: where relative necessity and relative sufficiency diverge, the more sufficient cause will tend to be

less likely and to have a lower correlation with the event (unless the more necessary cause is extremely likely). Our subjects may have chosen the more necessary cause because they were relying on some intuitive measure of bidirectional correlation.

Experiment 2 asked whether subjects would choose more necessary causes when they were <u>not</u> more highly correlated with the event.

3. EXPERIMENT 2

3.1 Method

3.1.1 Design. Four groups of subjects participated in Experiment 2. Each answered questions pertaining to the four items in Table 2-3. Group A was given the four items in Table 2-3 and asked to fill in 2 x 2 tables relating each of the causes to the event. Specifically, they filled in each cell with the number of people out of 100 who would fit that description. For example, one cell for item 1 was (lives alone, is unmarried). Once completed, these contingency tables can be used to test the speculations about correlation and likelihood presented in the above discussion. After filling in both 2 x 2 tables for an item, subjects selected the cause which provided a better explanation. Aside from providing a replication of Experiment 1, these choices can be related to the chosen causes' relative necessity, sufficiency, likelihood and correlation with event. Although promising in design, this task is quite difficult for subjects.

A less demanding way to unconfound probabilities and correlations is to specify them. Groups B and C saw 2 x 2 contingency tables relating each event to each possible cause. These tables were filled in so that: (a) one cause was more necessary; (b) the other was more sufficient; and (c) the more sufficient cause also bore a higher correlation with the event than did the more necessary cause. After studying the information in the tables, subjects selected the cause which provided the best explanation. They were also asked to explain their choices. Group B saw the actual tables; Group C received a verbal description of their contents. Correlations were measured by ϕ (phi). Since there is no guarantee that subjects'

perceptions of these correlations will correspond to their value according to ϕ, a fourth group (D) received the 2 x 2 tables with neutral labels and a description of what correlations are. They were asked to estimate the correlations they saw.

3.1.2 Stimuli. Table 2-2 presents the 2 x 2 tables shown to subjects in Groups B, C, and D. For each item, one cause is more necessary, while the other is more sufficient; the more sufficient cause is more highly correlated with the event. Since the more sufficient cause is always relatively unlikely, yielding extreme marginals, most phi values are fairly small.

3.1.3 Procedure. Instructions were straightforward and are available upon request. Care was taken not to overwhelm subjects (particularly in Group A) and not to emphasize either the information relevant to necessity or that relevant to sufficiency. Group A instructions were supplemented with a blackboard demonstration showing how to fill in a sample contingency table. Group D's instructions included four labeled 2 x 2 tables, showing correlations of 1.0, .00, .14, and .78. In order to give a concrete context, both these instructional tables and those on which subjects were tested were labeled rain/no rain for the columns and cloud seeding/no cloud seeding on the rows. After the instructions, the eight contingency tables shown in Table 2-2 were presented, along with two additional tables showing correlations of .00 and 1.0. These were included to test subjects' understanding of the instructions.

3.1.4 Subjects. One hundred and seven subjects were recruited as in Experiment 1.

3.2 Results

3.2.1 Group D. The contingency tables used in Groups B and C were designed so that the more sufficient cause bore a higher correlation with the event. Group D was asked to judge these correlations in a neutral context in order to see if the ordering of calculated correlations was also the ordering of perceived correlations. Fourteen of 18 subjects correctly assigned a value of 0 to the added table showing no correlation and 1.0 to the table shown full correlation; data from the other four subjects were deleted. Table 3-1 presents relevant data for the 14 remaining subjects. For items 1, 2, and 3, the majority of subjects assigned a higher subjective correlation to the table which bore a higher computer correlation. In each case, the magnitude of the differences was statistically significant. For item 4, the two correlations were seen as equally large (seven subjects viewed each as larger). If we assume that subjects in Groups B and C attributed similar subjective correlations, then they saw the more necessary cause as having a lower correlation with the event for items 1, 2, and 3, and an equal correlation in item 4. Thus, item 4 provides a valid but less stringent test of their preference for necessity.

3.2.2 Groups B and C. Table 3-2 shows the number of subjects who, after seeing the statistical cause-event data, picked each possible cause as providing the better explanation. Responses of those who saw the tabular version (Group B) and of those who saw the verbal version (Group C) were quite similar and are discussed together. As in Experiment 1, subjects consistently thought that the more necessary cause (the first in each pair) provided a better explanation than the more sufficient (and

TABLE 3-1

SUBJECTIVE ESTIMATES OF CORRELATIONS IN CONTINGENCY TABLES

Group D - Experiment 2

Item	Cause	Computed ϕ	Mean Estimated ϕ (N=14)	t for difference between ϕ ests.[a] (df = 13)
1.	More necessary	.25	.25	3.83**
	More sufficient	.34	.46	
2.	More necessary	.00	.15	3.63**
	More sufficient	.38	.47	
3.	More necessary	.00	.15	2.55*
	More sufficient	.30	.44	
4.	More necessary	.30	.35	-0.37
	More sufficient	.33	.32	

[a]Positive sign indicates the direction of difference was same for computed and estimated

*p .025

**p .005

TABLE 3-2

NUMBER OF SUBJECTS CHOOSING EACH ALTERNATIVE
AS PROVIDING A BETTER EXPLANATION IN EXPERIMENT 2

Events and Alternatives		Tabular Presentation (Group B)	Verbal Presentation (Group C)	Total
Event 1:	Lives alone			
a.	is unmarried	18	18	36
b.	is a shy, easily embarrassed recluse	6	2	8
c.	no difference	7	9	16
Event 2:	Is a heavy smoker			
a.	has friends who smoke	15	17	32
b.	has a deep-seated inferiority complex	7	5	12
c.	no difference	9	7	16
Event 3:	Signs a "Jail Nixon" petition			
a.	Republican upset with Watergate	19	18	37
b.	FBI agent looking into subversion activities	4	1	5
c.	no difference	8	10	18
Event 4:	Works as a computer programmer			
a.	orderly	18	12	30
b.	avid "Star Trek" fan	3	7	10
c.	no difference	10	10	20

more highly correlated) cause ($p \leq .002$ in each case; sign test). The proportion of "no difference" responses was, however, higher here (.29) than for the same four items in Experiment 1 (.16). Among subjects who did choose between A and B, the proportion selecting A (i.e., A/AB) was quite similar in the two experiments, for each of the 4 items ($p > .10$) and overall (.78 for Experiment 1 vs. .79 for Experiment 2).

Most subjects who chose the more necessary cause explained that choice by some version of the retrospective probability criterion; most who chose the more sufficient cause invoked the prospective probability criterion. A few subjects used both of these criteria (on different questions). A few subjects selected the more necessary cause because it was generally more likely (i.e., not just as an antecedent); on item 3 two subjects invoked the sophisticated argument that FBI agents are so rare that one cannot trust statistics on their prevalence and behavior. Several subjects invoked substantive reasons which ignored the tabled statistics; a few gave incoherent responses.

3.2.3 Group A. Composing contingency tables proved to be quite difficult: on each item, two to four subjects (of 33) failed to complete the task correctly; their data were deleted. About 5% of the tables contained values which seemed substantively unreasonable (e.g., 68% of the population are computer programmers). Although dubious, such responses were retained. Subjects found no difference between the two causes in explanatory adequacy 39% of the time, a considerably higher rate than previous groups and possibly another expression of confusion. Because of these difficulities, we would view the following results with some reservation.

Table 3-3 presents mean responses. Although none of these contingency tables matches those shown to Groups B and C, the patterns are sufficiently similar to suggest that the values shown those groups were plausible. Table 3-3 differs from Table 2-2 primarily in the inflated values given by Group A to events which were quite rare in the tables presented to Groups B and C (e.g., Groups B and C were told that there were 1% FBI agents in the population of item 3; Group A estimated 10%, suggesting either unreasonably high responses or a generally high level of paranoia).

For each of the four items, the more necessary cause (as measured by $P(C_i|E)$) according to these group judgments, was the same as in Groups B and C. These were also the causes judged to be more necessary in Experiment 1. However, in contrast with Experiment 1 and with Groups B and C, the two possible causes have roughly similar sufficiency (as measured by $P(E|C_i)$). Thus, the less necessary cause was judged equally, not more, sufficient. These group results are borne out in the tables produced by individual subjects (see Table 3-4). The cause designed to be more necessary almost always was so; it was also judged more likely. The two causes were, however, similar in their sufficiency. Table 3-4 also shows that Group A subjects agreed with other groups regarding which cause provides a better explanation. Were subjects guided by considerations of sufficiency, they presumably would have found no difference in these paired causes regarding explanatory adequacy. The equal sufficiency of these causes does, however, make the present evidence for reliance on necessity weaker than that found elsewhere.

TABLE 3-3

MEAN RESPONSES IN CONTINGENCY TABLES COMPLETED BY GROUP A, EXPERIMENT 2

Item 1			
	Lives alone	Does not live alone	Phi
Unmarried	20.5	20.3	.38
Married	9.1	50.1	
Recluse	11.3	13.4	.20
Not a recluse	18.4	57.0	
Item 2			
	Heavy smoker	Not a heavy smoker	
Friends who smoke	29.5	41.3	.17
No friends who smoke	7.0	22.2	
Inferiority complex	11.9	10.7	.18
No inferiority complex	24.7	52.8	
Item 3			
	Signs petition	Does not sign petition	
Upset Republican	10.6	24.0	.16
Not an upset Republican	30.7	34.7	
FBI agent	3.7	6.3	.03
Not an FBI agent	37.6	52.4	
Item 4			
	Works as programmer	Does not work as programmer	Phi
Orderly	14.0	41.4	.17
Not orderly	5.2	39.4	
"Star Trek" fan	9.9	30.1	.11
Not a "Star Trek" fan	9.3	50.6	

TABLE 3-4

EVALUATION OF CAUSES BY GROUP A, EXPERIMENT 2

Cause	More likely	More necessary	More sufficient	Better explanation
Item 1				
a. Unmarried	21	26	17	18
b. Recluse	6	2	10	1
c. Neither	3	2	3	14
Item 2				
a. Friends who smoke	26	27	9	20
b. Inferiority complex	1	2	17	2
c. Neither	2	0	3	11
Item 3				
a. Upset Republican	27	27	11	21
b. FBI agent	3	1	16	2
c. Neither	1	3	4	10
Item 4				
a. Orderly	21	20	16	13
b. Star Trek fan	6	3	10	3
c. Neither	4	8	5	17
Total				
a. More necessary	95	100	53	72
b. More sufficient	16	8	53	8
c. Neither	10	13	15	52

NOTE: Subjects directly indicated which cause provided the better explanation. The other three judgments were inferred from the values in individual subjects' contengency tables.

The tables produced by individual subjects provide a cleaner test of the relationship between necessity, sufficiency and explanatory adequacy. There were 43 cases in which these tables indicated that one cause was more sufficient and the other one more necessary. In 27 of these cases, subjects chose the more necessary cause as the better explanation, in 3 they chose the more sufficient cause, and in 13 they chose neither cause.

Finally, in 31 of the 59 cases in which one cause was both more necessary <u>and</u> more sufficient, subjects thought that that cause provided a more adequate explanation; in 6 cases, they preferred the other cause; and in 22 cases, they were indecisive.

4. DISCUSSION

In general, a possible cause that is judged to be a good explanation has a lot going for it. It is realtively likely given the occurrence of the event; it makes the event relatively likely; it forms a coherent narrative when combined with the event; it "fits" the event; it makes it easy to see how the event occurred. That is, each of these five criteria produces judgments similar to those elicited by the other four and by the question "how adequate an explanation is this?"

Our efforts to produce items which discriminated between these judgments were only partially successful. Three ways of phrasing the question "which is a more adequate explanation?" produced nearly identical responses. Possibly, the formal distinctions between these criteria have *no subjective relevance*. The main difference between Explanations 2 and 3 is that the former makes no mention of the overall likelihood (base rate) of the causes. Some of the results from Experiment 2, however, suggest that overall likelihood may be hard to ignore in hunting for explanations. Explanations 1 and 3 differ in whether one or both of the possible causes was in fact present. Research by Kelley (1973) and Shaklee and Fischhoff (1977) has shown that when one possible cause is known to have been present, people tend to discount the involvement and presence of the other. Thus, this distinction, too, may have been subjectively muddled. It remains to be seen, though, whether other items or elicitation precedures will also produce similar judgments for these three explanation questions. For example, although the formal difference between Explanation 2 and Explanation 3 may be substantial, the questionnaires used here differed in but a word or two.

Three other judgments which produced similar responses were retrospective probabilities, representativeness and availability. Apparently, people engage in similar thought processes when asked how likely a cause is given an event, how well the event fits the cause and how readily one can see how the event occurred given the cause. These three criteria were called the "necessity" cluster because the retrospective probability criterion is a measure of the necessity of a cause given an event.

A distinct "sufficiency" cluster included prospective probabilities and coherence. The similarity of prospective probabilities and coherence suggests that the latter question elicits a sort of forward-looking perspective. Even though these two criteria are often contrasted in philosophical discussions, as presently operationalized, they did not differ subjectively. The fact that neither was a very good predictor of judgments of explanatory adequacy in the items remaining after wave 2 suggests that neither embodies all of what people do "naturally" when they evaluate possible explanations.

To the extent that judgments of necessity and sufficiency diverged, the former was a much better predictor of explanatory adequacy.

Experiment 2 replicated the choice of better explanation found in Experiment 1. It also showed that the choice was not due to there being a higher correlation between the more necessary cause and the event. Subjects preferred the more necessary cause even when it bore a lower correlation, as measured both by ϕ and by subjects' intuitive correlation coefficient (Group D).

If people do base their judgments of explanatory adequacy on the degree of covariation between causes and events, they measure covariation by an asymmetrical measure. That is, they are more concerned with the predictability of causes from events than of events from causes.

Because of the fact that when necessity and sufficiency diverge, the more necessary cause must be the more likely, we cannot exclude the possibility that people simply prefer to use more likely causes in their explanations. Although many investigators have found that people often ignore base rate information (Kahneman and Tversky, 1973; Nisbett and Borgida, 1975), several recent studies have shown that such information can influence judgment if it is perceived to have causal significance (Ajzen, 1977; Tversky and Kahneman, 1977). The present base rate information was designed to be causally relevant. Carried to the extreme, however, such reliance on likely causes seems implausible; for example, "X was breathing" would then be a widely invoked cause.

An important question for future research is what are the conditions, if any, under which people will prefer more sufficient causes to more necessary causes as explanations. Philosophers have discussed at length how an explainer's goals can change the explanations he or she finds adequate (e.g., Achinstein, 1977). No one knows which of these often subtle distinctions has psychological reality. One speculation is that people will prefer more sufficient explanations when they are explaining for the sake of future prediction. Identification of a sufficient cause means that the event will happen. Identification of a necessary cause only implies that it might.

5. FOOTNOTES

1. These accounts of two intricate philosophies of science are extraordinarily abbreviated. Additional discussion and fuller references may be found in Achinstein (1977), Evered (1976), or Fischhoff (1976).

2. These deletions included 4 of Bear's 5 items. For the fifth, there was a significant <u>disagreement</u> between the two groups (Explanation 2 and prospective probabilities) which most closely resembled the two groups which <u>agreed</u> in this experiment.

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Subcontract 78-072-0722

9. PERFORMING ORGANIZATION NAME AND ADDRESS
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10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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11. CONTROLLING OFFICE NAME AND ADDRESS
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12. REPORT DATE
November 1977

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
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18. SUPPLEMENTARY NOTES
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Explanation
Attribution
Perceived Correlation
Necessary and Sufficient Causes
Prediction

C sub 1   C sub 2

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A correlational design was used to investigate the subjective criterion which people invoke when asked "which of the following causes, C_1 or C_2, makes a better explanation of event E?" Five possible subjective criteria were tested: (a) $P(C_i|E)$; (b) $P(E|C_i)$; (c) the coherence of the narrative created by concatenating E and C_i; (d) how well each C_i fit or suited E; and (e) how readily one could see how C_i led to E. A pool of items was developed which (over)

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discriminated between some of these criteria. Two clusters of criteria emerged, one including (b) and (c), and the other the remaining three criteria. The latter cluster, including the judgment of how likely a cause was to be present given the occurrence of the event, proved to be a superior predictor of judgments of explanatory adequacy. A second experiment replicated these preferences and showed that they were obtained even when the cause indicated by the second cluster was less highly correlated with the event than the cause indicated by the first cluster. These results are discussed in terms of the descriptive validity of attribution theory, the psychology of explanation and the validity of people's intuitive explanations.